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Implementation of Lumi-Based ESD Learning to Train Systems Thinking and Digital Literacy in the Context of SDGs 15

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Abstract

Background: This research is motivated by students' systems thinking competence and digital literacy, which are still very low. This is due to the delivery of biodiversity material, which is still very conventional, and learning that is still teacher-centred. Therefore, this research will use the application of Lumi-based ESD learning. This research aims to determine the effect of implementing Lumi-based ESD learning to train systems thinking and digital literacy in the context of SDGs 15. **Method:** The type of research used in this research is Quasi Experiment with a Non-Equivalent Control Group Design research design. The sampling technique uses purposive sampling, namely class X1 as the experimental class and X5 as the control class. The instruments used were systems thinking competency tests, digital literacy questionnaires, attitude scale sheets, and student response questionnaires. **Results:** The research results stated that the N-Gain Value of systems thinking competency in the experimental class was outstanding, with a value of 0.65 in the medium category compared to the control class, with a value of 0.29 in the low category. Meanwhile, the N-Gain digital literacy value of students in the experimental class, with a value of 0.45 in the medium category, was compared with the control class, with a value of 0.18 in the low category. Judging from the hypothesis test, systems thinking, and digital literacy show significant differences with both values at sig (2-tailed) 0.00. **Conclusion:** From this research, it can be concluded that applying Lumibased ESD learning affects practicing systems thinking and digital literacy in SDGs 15. The findings in this research are that applying Lumi-based ESD learning is much better for practicing systems thinking competencies than digital literacy.

Keywords: Digital Literacy; Lumi; SDGs 15; Sustainable Development Education; Systems Thinking.

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Introduction

Education plays a role in developing and preparing the younger generation, who can cope with rapidly changing social conditions and transform society to be more sustainable. Education in Indonesia must play a positive role in realizing ESD (Education for Sustainable Development) or education for sustainable development in the future. Education for sustainable development is one of the individual efforts that will contribute to realizing more sustainable social, economic, and community environments (Kusanagi, 2020); therefore, by implementing ESD in learning, positive results are obtained. Student learning outcomes and skills increase. ESD competencies can be included in science learning to improve sustainable development and achieve SDGs (Purnamasari., et al., 2021).

According to UNESCO, education through ESD is a learning process or teaching approach based on sustainability principles at all levels and multidisciplinary fields of knowledge (Leicht et al., 2018). There are 17 goals with 169 measurable Sustainable Development achievements called Sustainable Development Goals (SDGs) or sustainable development goals. One of the efforts to realize the SDGs is through education. Education can be described as a great hope for designing a better sustainable future and an effort to overcome the environmental crisis (Almualimah et al., 2022).

The ESD concept focuses on developing and strengthening individual competencies; ESD (Education for Sustainable Development) establishes eight competencies that students must have to increase their creativity, find solutions, and develop their activities. One is systems thinking competency, an essential competency in ESD because ESD aims to expand the goal of thinking about systems in education. This goal includes cognitive aspects and students' problem-solving abilities, life skills, and attitudes that can be connected to the system (Wienert, 2001).

WWF (World Wild Fund) developed a systems thinking paradigm from a New Perspective on Thinking and Learning for Sustainability. This paradigm uses the systems thinking method, a learning support activity program that aims to shape students' character so that they can think systemically by using an environmental understanding approach from planet Earth to ecosystems (Melinda, 2018). Systems thinking competency is an essential skill for learners in the 21st century. By studying this competency in the context of biology, learners can develop the knowledge, skills, and values needed to make responsible and sustainable decisions related to the environment and development (Rustaman, 2019).

Based on Dawidowicz (2012), systems thinking competency is a competency that aims to enable students to learn to make decisions in solving complex life problems (Agustina, 2019). Systems thinking competency is one of the competencies that students must achieve to equip future generations to survive in the 21st century. Students with sound systems thinking skills will understand the content well, even though they do not study each component specifically, but not vice versa (Meilinda et al., 2018). Rapid advances in science and technology have occurred over the past twenty years. Based on the 21st Century Learning Framework (Peppler, 2017), the skills needed in this century include contextual learning, technology, and the ability to collaborate, communicate, solve problems, and think critically and creatively (Inayah et al., 2023). One of the 21st-century skills is technological skills; therefore, it is in line with Muslimin & Rahmatan (2020), through digital literacy skills that are always needed to access information that should be used ethically and wisely by current technological advances (Sulistyarini et al., 2022). The American Library Association defines digital literacy as using information and communication technology to find, understand, evaluate, create, and communicate digital information. This ability requires cognitive and technical skills (Hunter, 2018). In line with Rahman et al. (2024), digital literacy can improve students' thinking skills, especially problem-solving, and enhance their beneficial communication skills, especially in the current era of globalization.

Based on the results of a preliminary study obtained through interviews with teachers at MAN 2 Sukabumi City, it was found that students' systems thinking and digital literacy competencies in schools still need to be improved. This is indicated because some students still have not explored their knowledge of the concept of interrelated material, namely the ability to recognize and understand problem relationships and analyze complex systems. The teacher also said that most students put more effort into critical thinking skills to decide on actions. At the same time, digital literacy can be seen from how students' learning is still driven by books and student worksheets provided by the school. The researcher concluded the interview results, indicating that, despite the approach that considers environmental issues and problems in more depth, students' systems thinking and digital literacy abilities are still lacking in the learning process.

Thus, one way to train systems thinking and digital literacy is with interactive learning media. Based on Mayer (2002), students' systems thinking competencies can be taught using the right interactive learning media; selecting the right interactive learning media can

determine the success of developing students' systems thinking competencies (Hendi et al., 2020). Interactive media can make students more interested in sources of questions that will help them change the system; therefore, the interactive media that researchers use is lumi interactive media. Lumi Interactive Media is an application that offers more than 60 types of interactive and free digital content that teachers and other users can select for free. In addition to producing learning media in the form of interactive multimedia, Lumi also makes it easy for teachers to easily share their learning media using this lumi in the form of HTML files (H5P package) that can be accessed online (Veby et al., 2023) so that it can increase students' digital literacy. By using multimedia technology, learning activities that use digital media are more effective than conventional learning approaches that rely on textbooks (Yuniarti et al., 2023). Mistakes in the implementation of biology learning must not be repeated. Therefore, one way to overcome the problems experienced by students is learning that can encourage students to develop systems thinking competencies and digital literacy. This learning is by implementing Lumi-based ESD learning.

Education for Sustainable Development is a tool to achieve sustainable development or SDGs because education is responsible for preparing everyone to face and respond to the challenges of the 21st century, one of which is technology-related. This study uses the application of technology to learning media. In the learning process, UNESCO has compiled 3 ESD pillars, including the environment, economy, and socio-culture (Primasti, 2021). Based on this, it can be linked to biology learning subjects, one of which is biodiversity material, which is aligned with the SDGs goals in point 15, namely Life on Land, which states that protecting, restoring, and improving the sustainable application of terrestrial ecosystems, managing forests sustainably, stopping land degradation, and stopping biodiversity loss (UNESCO, 2018). This media can be created using interactive lumi media, enabling teachers to create interesting, practical, flexible, and innovative teaching materials.

Based on this background, this study aims to see the effect of implementing lumi-based Education Sustainable Development learning to train systems thinking and digital literacy in the context of SDGs 15. This study is expected to help students understand complex concepts. In addition, it can be a basis for development research in biology learning. Teachers can also use the application of lumi-based ESD learning as an alternative in the learning process.

Method

This study uses a quasi-experiment research type with a research design, namely, a non-equivalent control group design. At the beginning of the study, both classes were given a pretest. In the experimental class, the application of lumi-based ESD learning was given. In contrast, the control class used conventional learning such as discussion, presentation, and learning that refers only to student worksheets. After treatment, both classes were given a post-test, and then the results of the two tests in each class were compared. The research design that will be carried out can be seen in Table 1.

Table 1. Research Design Non-equivalent Control Group Design

Class	Pretest	Treatment	Post-test
Experiment	O_1	X	0_2
Control	O_3	X	0_4

(Source: Sugiono, 2017)

Information:
O1: Pretest in Experimental class
O2: Posttest in Experimental class
X1: Treatment of Lumi-based ESD Learning Implementation
X2: Treatment of Conventional Learning Implementation
O3: Pretest in control class
04: Post-test in the control class

Sample or Participants

This research was conducted at MAN 2 Sukabumi City, located at Jl. Palasari No. 14, Sukakarya, Kec. Warudoyong, Sukabumi City. The time of implementation of this research was carried out in May 2024 for two weeks. The object of the study was class X students of the 2023/2024 academic year who were in the even semester. In this study, two classes were selected as samples, namely class X1 and X5, which were selected using purposive sampling techniques, each class consisting of 39 students.

Instruments

Data collection was carried out using test and questionnaire techniques so that there were four research instruments used as tools in collecting data in this study consisting of: 1) systems thinking competency questions consisting of 8 essay questions used to measure students' systems thinking competency; 2) digital literacy questionnaire consisting of 18 statement items (positive and negative statements each consisting of nine statements); 3) systems thinking attitude scale questionnaire consisting of 8 statement items; and 4) participant response questionnaire to the application of lumi-based ESD learning to systems thinking and digital literacy with the context of SDGs 15 consisting of 8 statement items.

Table 2. Research Instrument Indicators

Research Instrument	Indicators
Systems Thinking Competency (UNESCO, 2020)	1. Recognizing and understanding relationships 2. Analyzing complex systems 3. Thinking about how a system is in different areas and sizes 4. Making decisions in sustainable discourse as a solution to the uncertainty of a problem phenomenon faced
Digital Literacy (Hague and Payton, 2010)	1. ICT Skills Ability 2. Ability to participate in digital space 3. Able to explain and negotiate ideas with others in digital groups 4. Able to communicate through digital technology media *5.* Able to understand and comprehend the Audience 6. Ability to search for and select information 7. Able to contribute, analyze, and sharpen critical thinking when dealing with information 8. In line with the context of social and cultural understanding 9. Ensuring security when users explore, create, and collaborate with digital technology
Systems Thinking Attitude Scale	1. Recognizing and understanding relationships 2. Analyzing complex systems 3. Thinking about how a system is in different areas and sizes 4. Making decisions in sustainable discourse as a solution to the uncertainty of a problem phenomenon faced.
Student Responses	1. Student responses to the implementation of ESD learning based on Lumi interactive media 2. Student assessment of the implementation of ESD learning based on lumi interactive media towards systems thinking competencies 3. Student assessment of the implementation of ESD learning based on lumi interactive media toward digital literacy skills 4. Student assessment of the implementation of ESD learning based on lumi interactive media towards biodiversity material

Questionnaires and test questions were given to the experimental and control classes during the pretest and post-test. In addition to the digital literacy questionnaire, the attitude scale and the students' systems thinking test questions were also given a student response questionnaire in the experimental class at the end of the learning. The questionnaire used a Likert scale to determine students' responses to the teaching that had been carried out.

Data analysis

The research data results were analyzed statistically using the SPSS version 27.0.1 application and Microsoft Excel. The pretest and post-test score data processing includes parametric analysis prerequisite tests (normality and homogeneity tests) and hypothesis testing, which were analyzed using the t-test (independent t-test). In addition, the N-Gain test was also carried out for systems thinking competencies, digital literacy, and attitude scales. The data analysis technique for the student response questionnaire was analyzed using a Likert scale with four alternative answers, namely Strongly Agree, Agree, Disagree, and Strongly Disagree (Sugiyono, 2022).

Table 3. N-Gain Criteria

N-Gain Range	Category
-1.00 ≤ g < 0,00	There is a decrease
g = 0,00	There is no increase
0,00 < g < 0,30	Low
0,30 ≤ g< 0,70	Medium
0,70 ≤ g ≤ 1.0	High

(Source: Irma, 2024)

Result

The data obtained in this study are data collected from the systems thinking competency test, digital literacy questionnaire, attitude scale questionnaire in the form of pretest and post-test given to the experimental class and control class, and student response questionnaire in the experimental class. The treatment given to learning biodiversity material in the experimental class uses lumi-based ESD learning. In contrast, in the control class, treatment is given by applying conventional knowledge. For example, learning is still centered on the teacher, one-way teaching, discussion, and learning using student worksheet textbooks as the primary source. The pretest is given before learning (before being given treatment), which aims to determine the extent of the initial abilities of students in the experimental class and control classes. At the same time, the post-test is given after the learning process is carried out to determine the extent of students' systems thinking competency and digital literacy after being given treatment and assess the effect of applying lumi-based ESD learning in the experimental class. Based on the data collected, an overview of the data that has been obtained will be explained.

Category Based on N-Gain

Analysis of systems thinking and digital literacy tests using N-Gain calculations aims to determine the value criteria or show an increase in student abilities. The comparison graph of N-Gain values between the experimental and control classes based on the pretest and post-test values is presented in Figure 1.

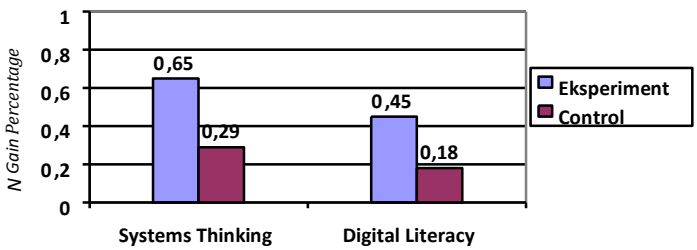

Figure 1. Categories Based on N-Gain

After calculating the N-Gain, the pretest and post-test scores show that the experimental class is superior in systems thinking with an N-Gain score of 0.65 in the moderate category and digital literacy at an N-Gain score of 0.45 in the mild category.

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Table 4. Recapitulation of Systems Thinking and Digital Literacy Data Pretest and Post-test Scores

Data	Class	Average Value			Category N-Gain
		Pretest	Posttest	N-Gain	
System Thinking	Experiment	55,02±8,82	85,10±7,43	0,65±0,19	Medium
	Control	46,58±8,87	71,26±5,57	0,29±0,13	Low
Digital Literacy	Experiment	64,21±4,23	82,02±3,96	0,45±0,13	Medium
	Control	67,91±4,42	73,71±4,89	0,18±0,09	Low

Statistical Test Results of Systems Thinking and Digital Literacy

The pretest and post-test score data of systems thinking and digital literacy competencies were then subjected to prerequisite analysis tests such as normality, homogeneity, and hypothesis tests. The results of the pretest and post-test normality and homogeneity tests in the experimental and control classes of systems thinking and digital literacy obtained data that were normally distributed and homogeneously distributed with sig values> 0.05, then a post-test hypothesis test was carried out in the experimental and control classes using an independent sample t-test showing that the data was significantly different with both results sig <0.05, namely sig (2-tailed) 0.00 so that the H0 hypothesis was not accepted while H1 was accepted. This shows that implementing lumi-based ESD learning affects training students' systems thinking and digital literacy competencies.

Achievements Per Indicator of Systems Thinking Based on Test Results

The results of the systems thinking competency post-test in this study using four indicators according to UNESCO (2020) can be seen in Figure 2.

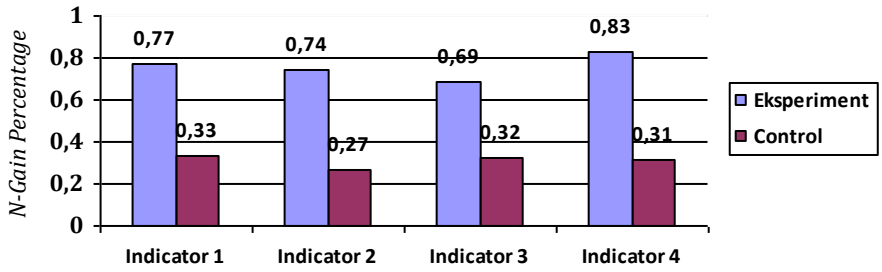

Figure 2. N-Gain Value of Systems Thinking Per Indicator

Based on Figure 2, it can be concluded that applying lumi-based ESD learning to train systems thinking applied to the experimental class is very good on indicator 4 with a value of 0.83. Indicator 4 is making decisions in continuous discourse to solve the uncertainty of a problem phenomenon. The lowest value is shown by indicator 3, namely, thinking about how a system is in different areas and sizes, with a value of 0.69.

Achievement Per Indicator of Systems Thinking Based on Attitude Scale

The systems thinking competency test results are also supported by an attitude scale questionnaire, which can be seen in Figure 3.

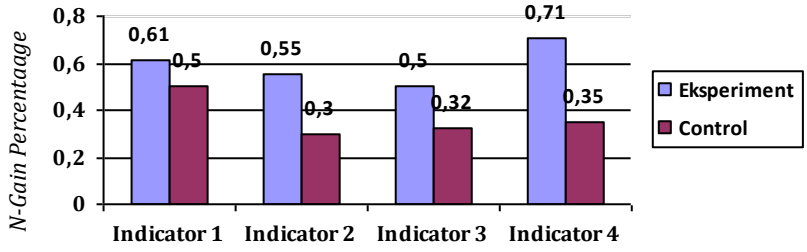

Figure 3. N-Gain Value of Systems Thinking Attitude Scale Per Indicator

Figure 3. proves that the value of the attitude scale toward systems thinking competency in the experimental class has the highest value of 0.71 on indicator four and the lowest value of 0.50 on indicator 3. Meanwhile, in the control class, the highest value is 0.50 on indicator 1, and the lowest value is 0.30 on indicator 2. This shows that the attitude scale follows the data on the systems thinking test shown in Figure 2. achievement per Digital Literacy Indicator

The digital literacy questionnaire measurement activity was carried out during the study by providing pretest questions before learning began, then after learning was completed, students were asked to fill in the post-test questions; the following statements use digital literacy indicators according to Hague and Payton (2010). The following are the pretest and post-test results in the experimental and control classes. The results of the pretest and post-test on digital literacy adjusted to 9 indicators can be seen in Figure 4.

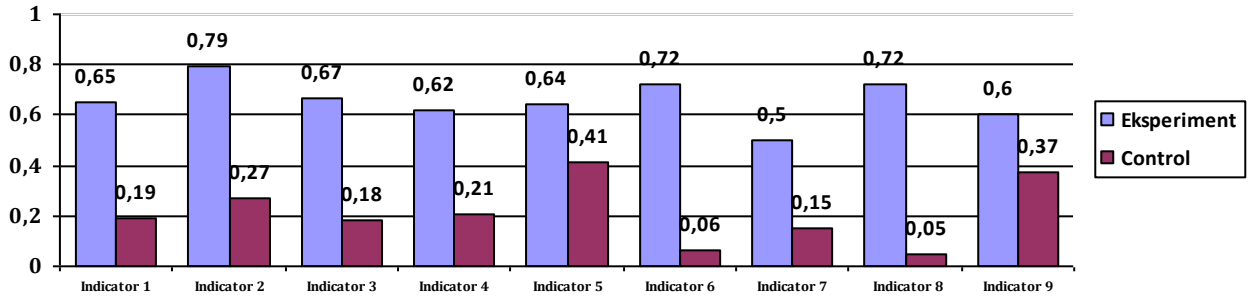

Figure 4. Digital Literacy N-Gain Value Per Indicator

Based on Figure 4, it can be concluded that applying lumi-based ESD learning to train digital literacy in the experimental class shows a good value compared to the control class. This is indicated by the highest value of the experimental class on indicator 2, namely the ability to participate in digital space, with the highest N-Gain Value of 0.79 in the high category and the lowest on indicator 7, namely being able to contribute, analyze and sharpen critical thinking when dealing with information with an N-Gain value of 0.50 in the medium category.

Student Responses to Systems Thinking and Digital Literacy

The superiority of the experimental class compared to the control class in systems thinking and digital literacy competencies is supported by positive student responses. This is shown in the following Table 5.

Table 5. Student Response Value Data

Aspects Revealed	Average value (%)	Category
Students' responses to the implementation of ESD learning based on Lumi interactive media	86.22	Very good
Students' assessment of the implementation of ESD learning based on lumi interactive media towards systems thinking competencies	90.71	Very good
Students' assessment of the implementation of ESD learning based on lumi interactive media towards digital literacy skills	89,10	Very good
Students' assessment of the implementation of ESD learning based on lumi interactive media towards biodiversity material	91.03	Very good
Average	**89.26**	**Very good**

Based on Table 6, it is known that student responses to all indicators are categorized as very good. Overall, the final score from the student response questionnaire was 89.26%, so it can be seen that students positively responded to applying lumi-based ESD learning to train systems thinking and digital literacy in the context of SDGs 15. Because this material presents many problems regarding biodiversity and is presented using applications, learning that uses the application of ESD makes learning more interesting and more understanding of the material.

Discussion

The effect of implementing lumi-based ESD learning

In the learning process, there were differences in the provision of treatment in the experimental and control classes. In the experimental class, the application of lumi-based ESD learning was given. In contrast, conventional learning was applied in the control class, such as teacher-centered learning, one-way teaching, discussion, and using textbooks. Student worksheets as the primary source. In the implementation of the experimental class and the control class before being given treatment, each worked on a pretest of the system thinking competency test, digital literacy questionnaire, and attitude scale questionnaire first, then at the end of the learning after being given treatment, students would be given a post-test to determine the effect on each variable.

The average N-Gain results of the system thinking competency and digital literacy in the experimental class in Figure 1 were higher than those in the control class. This is proven by the results of the post-test scores of the system thinking test and digital literacy questionnaire in the experimental class and control class so that it can be shown that the application of lumi-based ESD learning can train system thinking and digital literacy. This is based on research conducted by Melinda et al. (2018), which shows that students with sound systems thinking skills will understand the content well even though they do not study each component specifically, but vice versa. In line with Rahman et al. (2024), digital literacy can improve students' thinking skills, especially problem-solving and communication skills, which are very useful, especially in the current era of globalization.

After being given a post-test for the experimental class systems thinking test in Figure 1, the average N-Gain results were higher, with a value of 0.65, compared to the control class, which had a value of 0.29. This is because after implementing lumi-based ESD learning, students can search for and find their knowledge more independently. In this study, students were trained to observe global characteristics or problems expressed with what they obtained from their observations using lumi interactive media in line with Novianti (2023), who stated that finding solutions to problems and providing skills in providing solutions to issues, encourages students to look for existing problems and find solutions related to the topic. Therefore, ESD is a skill related to several combinations, such as critical thinking, making decisions in solving problems, planning, and creating structured solutions to issues (Pradipta et al., 2021).

The average N-Gain value after being given a post-test of the experimental class digital literacy questionnaire in Table 1 increased more with an N-Gain value of 0.45 than the

control class with an NGain value of 0.18. The experimental class uses digital learning media such as Lumi interactive media to train digital literacy. In line with Hendi et al. (2020), one of the school's solutions to train digital literacy is integrating technology into learning, which can be fulfilling technology-based learning facilities. The digital technology used in this study is lumi interactive media. Based on this, the experimental class was given a learning treatment using lumi interactive media, which presented problem-solving questions plus technological features that train digital literacy so that, in line with Rahmawati & Septiana (2021) that with digital literacy, students can learn to control themselves in making considerations and making their own decisions and knowing the flow system by using strategies responsibly. Digital literacy students possess life skills that include the ability to use technology, information, and communication, and students also include social skills, critical thinking skills, imaginative skills, and ideas (Eka & Okatariani, 2020).

The advantages of lumi interactive media are that it is easy to use because there are features that are easy for students to understand, can be accessed anywhere and anytime, can be saved and downloaded easily, engaging and very interactive, training students to have digital literacy skills and flexible learning times (Riyan, 2021). Through lumi interactive media, it also makes it easier for teachers to easily share their learning media using this lumi in the form of HTML files (H5P package), which can be accessed online and for free (Veby et al., 2023). According to Nur Hafifah & Harry Sulistyprete (2020), digital literacy can help someone become productive with fun learning and good use of technology, fostering student motivation (Hima, 2017).

This can be proven by the graph of post-test values per indicator in the experimental class, which is greater than the control class. This means that applying lumi-based ESD learning is more effective in training students' digital literacy than conventional learning applications. This is in line with Hutahaen et al. (2023), who stated that one of the advantages of interactive learning media is that they are interactive, which allows students to participate more actively and more freely in the learning process.

The hypothesis test results in Table 5 show a significant difference, so the H0 hypothesis is not accepted, while H1 is received with both sig values (2-tailed-) at 0.000. This indicates that implementing lumi-based ESD learning affects training systems thinking and digital literacy in the context of SDGs 15. This is in line with the theory that states based on Purnamasari (2021) that ESD provides students with knowledge, skills, values, and perspectives to process information, make decisions, and take responsible actions for the environment, economic sustainability, and just society for current and future generations. ESD is significant for achieving the SDGs because it helps foster understanding, attitudes, and values related to social, economic, and environmental life and provides broad and futuristic global insights (UNESCO, 2017; Rahman et al., 2019; Novidsa et al., 2020).

Systems Thinking Competence

Based on Figure 2 above, it can be concluded that applying lumi-based ESD learning to the experimental class can train students' systems thinking competencies. This is because, during the learning process in the experimental class, the biodiversity material is aligned with UNESCO Learning Objective point 15. Understanding complex and dynamic biodiversity systems thinking is critical. Systems thinking describes how each element in an ecosystem interacts and how changes to one element can impact the entire system. Species variation is not the only aspect of biodiversity. It also includes ecosystems and their interactions. This aligns with Abdurahman & Susana (2022), who stated that ESD learning can improve students' systems thinking competencies in effort and energy, which is essential for their understanding of ecosystems. In addition, it emphasizes its importance as a key competency that students must have to understand environmental dynamics (Nuraeni et al., 2022).

During learning, it does not only refer to student worksheets or reading textbooks, but students can think systematically with the presentation of materials, questions, and LKPD appropriate to the learning objectives without going beyond the curriculum available at school. Purnamasari et al. (2021), Inayah et al. (2023), and Misriani et al. (2023) also stated

that the application of ESD learning can be used to train students' systems thinking. In addition, the data above also shows differences in N-Gain values for each system thinking indicator in both the experimental and control classes. This is because each student has different systems thinking competencies, so there are differences in each indicator. In Figure 4, indicator 4, namely making decisions in continuous discourse as a solution to the uncertainty of a problem phenomenon faced, is the highest indicator with a high category in the experimental class. This is because, in the learning process, the teacher becomes the trigger for questions that make students answer by making decisions. Lempert et al. (2006) stated that making decisions in continuous discourse can anticipate future scenarios, and evaluating decision choices based on these scenarios is the core of a strong decision-making approach (Dewulf & Biesbroek, 2018). The data is also proven by the results of the attitude scale questionnaire, which obtained a value of 0.71 in the high category, which means that students have behavior related to this indicator.

Indicators 1, able to recognize and understand relationships in biodiversity, and 2, namely analyzing complex systems, have a moderate category in the experimental class. It can be concluded that students have behavior related to these indicators. This is in line with research that has been conducted by Misriani (2023), which states that these behaviors or activities include being able to pay attention and listen to the explanations received by considering various factors to understand them, being able to answer questions received with holistic thinking, and their activities can solve problems on difficult and very complex questions and can analyze questions according to facts in various environmental conditions. The data is proven by the attitude scale questionnaire, which obtained a value of 0.61 in indicator 1 and 0.55 in indicator 2, both of which are in the moderate category, which means that students have habits related to these indicators. Meanwhile, indicator 3, namely, thinking about how a system is in different areas and sizes, is the lowest even though it is still in the moderate category. This is because students are still less accustomed to doing these activities. These things include being unable to think about problems that arise during the learning process, being unable to distinguish issues based on relevant and irrelevant information, and not being able to answer questions about the problem quickly. Based on this, in line with Lipusari (2013), working memory capacity plays a vital role in a person's ability to filter relevant information from irrelevant information, affecting the efficiency of their problem-solving and decision-making. This is what causes the low value on indicator 3.

Based on the study's results, applying lumi-based ESD learning to train systems thinking is significantly different. This is evidenced by the results of the student response questionnaire in Table 5 aspect 2, namely student assessment of the application of lumi interactive media-based ESD learning on systems thinking competencies obtained a score of 90.71 with an excellent description.

Digital Literacy

Based on Figure 4, it can be concluded that applying lumi-based ESD learning to the experimental class can train students' systems thinking competencies. This is because, during the learning process in the experimental class using interactive lumi media to visualize biodiversity material aligned with UNESCO learning objective point 15, learning is more interesting and interactive and can help train students' digital literacy. These results align with research by Soraya et al. (2023); and Wilujeng et al. (2019) also stated that learning using interactive lumi media can train students' digital literacy. In addition, the data above also shows differences in N-Gain values for each digital literacy indicator in the experimental class. This is because each student has their skills, so there are differences in each indicator.

In Figure 4, it can be concluded that there are three indicators in the high category indicators, namely indicator two, the ability to participate in digital space, and indicator six, the ability to search for and select information. Indicator 9 ensures security when users explore, create, and collaborate with digital technology, with the highest value in indicator 2. This is because, in the learning process, students interact interactively with the content

provided by the teacher on the interactive lumi media, making learning more effective and interactive. Based on Munadi (2012), interactive media can offer an individual affective environment that is more effective, not forgetful, not bored, and very patient in following the desired instructions (Husein et al., 2015). This is in line with research conducted by Nugroho & Nasionalita (2020), which states that in addition to interacting, students can find and select information to carry out the process of dialogue, discussion, and building ideas by working together so that collaboration occurs to create an understanding and students are also able to guarantee security when users search with digital technology.

Judging from the differences in digital literacy indicators in the experimental and control classes, the experimental class is better. This is in line with the theory that states that low digital literacy in students is partly due to the use of conventional learning media or the absence of technological press, so there will be a decrease in student learning motivation; motivation has long been identified as a key parameter for student success and achievement. Motivation is a mental drive that drives and directs human behavior, including in learning activities; motivation drives someone to learn to achieve their desired goals (Datu et al., 2022). Students who have the desire and support within themselves to learn tend to be successful in terms of learning outcomes because students will be moved and directed in their attitudes and behavior in learning with increased motivation (Winarno & Ashari, 2022).

Meanwhile, indicator 7, namely being able to contribute, analyze, and sharpen critical thinking when dealing with information, is the lowest even though it is still in the moderate category. This is because students cannot still empathize with receiving and interpreting information passively and contributing, analyzing, and thinking critically when dealing with information. Emily (2017) stated that the development of information literacy involves the ability to find and interpret data and the capacity to contribute to creating and disseminating knowledge through criticism. This is what causes the low value in indicator 7.

From the explanation above, the results of the differences in indicators are very far apart, so it can be concluded that applying lumi-based ESD learning is very good for training digital literacy. Based on this, the positive student response to digital literacy in Table 5 Aspect 3, namely student assessment of the application of lumi interactive media-based ESD learning to digital literacy, obtained a value of 89.10 with an excellent description.

Conclusions

Based on the research and analysis that have been carried out, it can be seen that there is an influence of the application of lumi-based ESD learning to train systems thinking and digital literacy in the context of SDGs 15. This can be proven by the N-Gain value of systems thinking in the experimental class, which is very good, with a value of 0.65 in the medium category, compared to the control class, with a value of 0.29 in the low category. Meanwhile, the N-Gain Value of digital literacy in the experimental class is more excellent, with a value of 0.45 in the medium category, compared to the control class, with a value of 0.18 in the low category. This study's findings are that applying lumi-based ESD learning is much better for training systems thinking competencies than digital literacy. The limitation of this study is that it only focuses on the context of SDG point 15 (Life on land), so the results may not be generalized to other SDGs topics. Based on these limitations, the suggestion that can be given for further research is that a broader study needs to be conducted with a scope of other SDGs to see whether the application of lumi-based ESD learning remains effective even in the context of different SDGs.

Declaration statement

The authors report no potential conflict of interest.

References

Ackoff, R. L. (1994). *Systems Thinking And Thinking Systems*. System Dynamics Review.

Agustina, W, T, (2019). *Program Pembekalan Keterampilan Berpikir Sistem (KBS) dan Kreativitas Biologi Terapan. (BIORCE) Menggunakan Pendekatan Science-Technology-Religion-Engineering-Arts-Mathematics (STREAM)*

Almualimah. V. A , Ni'ma, S. M., Nurfitasari (2022). Pengembangan Smart Modul IPA Berbasis Education for Sustainable Motivasi Belajar sebagai Variabel Moderator. *Jurnal Educatio. 9*(2). 681-687.

Alpin, A., Khairul Nur Rahman, & Ichsan Fauzi Rachman. (2024). Analisis Kemampuan Literasi Digital pada Siswa Sekolah Dasar Sebagai Indikator Pencapaian SDGS 2030. *Jurnal Penelitian Pendidikan Indonesia (JPPI), 1*(3), 420-428. https://doi.org/10.62017/jppi.v1i3.1253

Andriani, N. D (2021). Analisis Rubrik Penilaian Berbasis Education for Sustainable Development dan Konteks Berpikir Sistem di Sekolah Dasar. *Edukatif: Jurnal Ilmu Pendidikan, 3*(4), 1326–1336. https://doi.org/10.31004/edukatif.v3i4.514

Atoy, J. M. B., Garcia, F. R. O., Cadungong, R. R., Cua, J. D. O., Mangunay, S. C., Guzman, A. B. D., (2020). Lingking Digital Literacy and Online Information Searching Strategies of Philippine University Students: The Moderating Role of Mindfulness. *Journal of Librarianship and Information Science. 52*(4), 1015-1027. http://dx.doi.org/10.1177/0961000619898213

Budijarto , A. (2020). Pengaruh Perubahan Sosial Terhadap Nilai-Nilai yang Terkandung Dalam Pancasila. *Jurnal Lemhannas RI, 6*(2), 5-21.

Claudhya. R. D. C., Wardhani, S., Nawawi, S., (2021). Pengembangan Asesment Biologi Berbasis Keterampilan Proses Sains (KPS) di SMA Kota Palembang. *BIOEDUKASI Jurnal Pendidikan Biologi, 12(1).* http://dx.doi.org/10.24127/bioedukasi.v12i1.3751

Datu, A. R., Tumurang, H. J., & Sumilat, J. M. (2022). Pengaruh Motivasi Belajar Terhadap Hasil Belajar Siswa di Tengah Pandemi Covid-19. *Jurnal Basicedu, 6*(2), 1959–1965. https://doi.org/10.31004/basicedu.v6i2.2285

Depany, P., D., (2023).Penerapan Media Pembelajaran Fisika Lumi Education Untuk Meningkatkan Kemampuan Berpikir Kritis Dan Komunikasi. *Jurnal Pendidikan Fisika, 10*(1), 60-71. http://dx.doi.org/10.21831/jpf.v10i1.19458

Dewulf, A., Biesbroek, R. (2018). Nine lives are involved in decision making: fire management strategies in environmental management. *Policy and Society, 37*(4), 441–458 https://doi.org/10.1080/14494035.2018.1504484

Dharma, S., (2022). Pengaruh Kecakapan Literasi Digital Terhadap Kinerja Guru Sekolah Menengah Kejuruan Negeri di Kabupaten Gowa. *Manajemen Pendidikan, 17*(2), 117-129. https://doi.org/10.23917/jmp.v17i2.17569

Eilks, I. (2015). Science education and education for sustainable development - justifications, models, practices and thinking instrument (CCSTI) for measuring system thinking on climate change content. *Journal of Physics: Conference Series, 1013*(1). https://doi.org/10.1088/1742- 6596/1013/1/012046

Engerman, J. A., Otto, R. F., (2021) The Shift to Digital : Designing for Learning from a Culturally Relevant Interactive Media Perspective. *Education Tech Research Dev*elopment, 69:301-305 https://doi.org/10.1007/s11423-020-09889-9

Ghina, N. I., Diana, R., Yayan, S., (2023). Analysis Of The Use Of Learning Media And The Implementation of Esd By Biology Teachers In Senior High School. *BIODIK: Jurnal Ilmiah Pendidikan Biologi, 9*(2), https://doi.org/10.1002/sdr.4260100206

Hague, C., & Payton, S. (2010). *Digital Literacy Across The Curriculum Key to themes: A Futurelab Handbook.* Retrived from: www.futurelab.org.uk

Hendi, A., Caswita, Haenilah, Y. E. (2020). Pengembangan Media Pembelajaran Interaktifberbasis Strategi Metakognitif untuk Meningkatkan Kemampuan Berpikir Kritis Siswa. *Jurnal Cendekia: Jurnal Pendidikan Matematika. 04*(02), 823-834. https://doi.org/10.31004/cendekia.v4i2.310

Hima, L. R. (2017). Pengaruh Pembelajaran Bauran (*Blended Learning*) Terhadap Motivasi Siswa Pada Materi Relasi Dan Fungsi. *JIPMat (Jurnal Ilmiah Pendidikan Matematika), 2*(1). https://doi.org/10.26877/jipmat.v2i1.1479

Hunter I (2018) Digital Literacy in The Workplace: A View From The Legal Sector. *Business Information Review 35*(2), 56–59. https://doi.org/10.1177/0266382118772675

Husein, S., Herayanti, L., & Gunawan, G. (2017). Pengaruh Penggunaan Multimedia Interaktif Terhadap Penguasaan Konsep dan Keterampilan Berpikir Kritis Siswa pada Materi Suhu dan Kalor. Jurnal Pendidikan Fisika Dan Teknologi, 1(3), 221–225. https://doi.org/10.29303/jpft.v1i3.262

Hutahaen, Aprileny, L., Siswandari, Harini (2019). Pemanfataan E-Module Interaktif Sebagai Media Pembelajaran di Era Revolusi Industri 4.0. Digital Library Universitas Negari Medan. Retrived from: https://digilib.unimed.ac.id/id/eprint/38744

Leicht, J. Heiss and W. J. Byun (2018). *Issues and trends in Education for Sustainable Development*.

Lipusari, A. (2013). Peran Sistem Informasi Manajemen (SIM) dalam Pengambilan Keputusan. *Jurnal STIE Semarang*, 5(1).

Meilinda, Rustaman, N. Y., Firman, H., & Tjasyono, B. (2018). Development and validation of climate change system perspectives. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(1), 149–158. https://doi.org/10.12973/eurasia.201 5.1313a

Novianti, R., Suhendar., Ratnasari, J., (2023) Pengembangan E-Module Berbasis Education for Sustainable Development untuk Melatihkan Keterampilan Berpikir Kritis pada Siswa. *Bioscientist: Jurnal Ilmiah Biologi, 11*(1). http://dx.doi.org/10.33394/bioscientist.v11i1.7986

Nugroho, C., Nasionalita, K. (2020). Indeks Literasi Digital Remaja di Indonesia Digital Literacy Index of Teenagers in Indonesia. *Jurnal Pekommas*, *5*(2), 215–223

Nuraeni, R., Setiono, Aliyah, H. (2020). Analisis Kemampuan Berpikir Sistem Siswa Kelas XI SMA pada Materi Sistem Pernapasan Manusia*. Jurnal Pedagogi Hayati, 4*(1)

Oktariani, Ekadiansyah, E. (2020). Peran Literasi dalam Pengembangan Kemampuan Berpikir Kritis. *Jurnal Penelitian Pendidikan, Psikologi dan Kesehatan, 1*(1), 23-33. https://doi.org/10.51849/j-p3k.v1i1.11

Peppler, K. (2017). 21st-Century Skills. *The SAGE Encyclopedia of Out-of-School Learning.* https://doi.org/10.4135/9781483385198.n301

Pratiwi, N. L. P. W., Dantes, N., Divayana. (2021) Pengembangan Modul Elektronik Berbasis Eduction for Sustainable Development Menggunakan Flip PDF Professional pada Muatan Pelajaran IPA Tema Lingkungan Sahabat Kita untuk Siswa Kelas V. *Jurnal Teknologi Pembelajaran Indonesia, 11*(2). https://doi.org/10.23887/jurnal_tp.v11i2.661

Purnamasari, S., Hanifah, N. A. (2021) Education for Sustainable Development (ESD) dalam Pembelajaran IPA. JKPI: Jurnal Kajian Pendidikan IPA, 1(2). https://doi.org/10.52434/jkpi21281

Rustaman, N. R. (2019). *Symposium on Biology Education 2019*.

Soraya, S. M., Kurjono, K., & Purnamasari, I. (2023). Pengaruh Literasi Digital Siswa Terhadap Hasil Belajar Siswa Dengan Motivasi Belajar sebagai Variabel Moderator. *Jurnal Educatio FKIP UNMA, 9*(2), 681–687. https://doi.org/10.31949/educatio.v9i2.4537

Sugiyono. (2017). *Metode Penelitian Pendidikan: Pendekatan Kuantitatif, Kualitatif, dan R&D. Bandung*: CV. Alfabeta.

Sugiyono. (2022). *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Alfabeta.

Sukarelawa, I. M., Indratno, K. T., Ayu, M. S (2024). *N-Gain vs Stacking Analisis Perubahan Abilitas Peserta Didik dalam Desain One Group Pretest-Posttest.* Surya Cahya

Sulistyarini, W., Fatonah, S. (2022). Pengaruh Pemahaman Literasi Digital dan Penerapan Media Pembelajaran Terhadap Keterampilan Pedagogik Guru Era Digital Learning. *Journal of Educational Learning and Innovation, 2*(1). https://doi.org/10.46229/elia.v2i1.383

UNESCO. (2018). *Pendidikan untuk pembangunan Berkelanjutan dan SDGs: Belajar Untuk Bertindak, Belajar untuk Mencapai Memajukan Kebijakan* PPB, 6.

UNESCO. (2017). *Education For Sustainable Development Goals*.

UNESCO. (2020). *Education For Sustainable Development Goals*.

Weinert, F. E. (2001). Concept of Competence: A Conceptual Clarifi Cation. In D. S. Rychen & L. H. Salganik (Eds.), Defi Ning And Selecting Key Competences (pp. 45–65). Göttingen, Germany: H

Wilujeng, I., Dwandaru, W. S. B., & Rauf, R. A. B. A. (2019). The Effectiveness Of Education For Environmental Sustainable Development To Enhance Environmental Literacy In Science Education: A Case Study Of Hydropower. *Jurnal Pendidikan IPA Indonesia, 8*(4), 521–528. https://doi.org/10.15294/jpii.v8i4.19 948

Yuniarti, A., Titin., Safarini, F., Rahmadia, I., Putri, S. (2023). Media Konvensional Dan Media Digital Dalam Pembelajaran. *Jurnal Education and Technology, 4*(2). https://doi.org/10.31932/jutech.v4i2.2920